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Multipurpose Silviculture in Ponderosa Pine Stands of the Montane Zone of Central Colorado

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Abstract

Presents silvicultural prescriptions for ponderosa pine in an area where several uses and products of the forest are important but scenic and recreation values predominate. Although far from virgin condition, the pine stands now bear little resemblance to a managed, regulated forest. Present diversity within and between vegetative types can and should be maintained.

Keywords: Forest cutting systems, *Pinus ponderosa,* silviculture, stand condition, thinning (trees), timber management.

Acknowledgment

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by

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Guides are presented here for silvicultural practices in ponderosa pine[2] stands of the Montane Zone of central Colorado. This Zone is the first timbered belt above the Plains on the east side of the Colorado Rockies, at elevations from about 6,500 to 9,400 ft (Miller and Choate 1964). Altitudinal limits vary locally with latitude, aspect, and soil depth. The Zone includes the eastern parts of the Arapaho-Roosevelt and Pike-San Isabel National Forests plus other lands along the same north-south axis.

Another way of locating the Zone geographically emphasizes its peculiar management problems and the need for multipurpose silviculture. It is the closest forest land to the largest cities of Colorado and to the homes of visitors from the East. The Zone, therefore, is the most heavily used timbered area of Colorado. Use is continuous, since the entire Zone is readily accessible yearlong for residence, recreation, and other purposes.

Soil and weather factors of the Montane Zone of central Colorado determine possible uses of the area, relative resistance of the land to abuse, and which silvicultural methods are practical. Annual precipitation is very low for tree growth, averaging from 15 to 20 inches. Seasonal distribution of precipitation, however, compensates to some extent for the small total amount. About two-thirds of the annual precipitation falls during spring and summer when it is most useful for regeneration and growth.

Geologically, the Montane Zone includes parts of the Front Range, Sangre de Cristo Mountains, Spanish Peaks, and the Wet Mountains. Soil parent materials of the Zone, therefore, include a full range of igneous, sedimentary, and metamorphic rocks and the alluvium derived from them (Marcus 1973). Residual soils of low fertility from several large granitic plutons cover much of the Zone. They are important factors in management decisions involving any resources and uses of the land because of potentially serious erosion following major disturbance of the vegetative cover.

For brevity, the term "Montane Zone" elsewhere in this publication refers only to that part described above, along the east side of the Rocky Mountains in central Colorado.

[2]Scientific names of species mentioned are listed on page 15.

The guides are based on (1) data from the Zone and from the Black Hills of South Dakota and Wyoming, and (2) experience gained during six applications of the marking prescriptions to a total of about 2,000 acres of the Manitou Experimental Forest, Colorado. In addition, operational utility of the prescriptions has been tested on the Pike-San Isabel Forest.

The Manitou Experimental Forest provides, on a small area, most of the land use situations faced by managers throughout the Montane Zone. The 2,000 acres referred to above lie along a main State highway and are adjacent to or visible from two campgrounds, a large picnic and fishing area, a rural housing development, and a church camp. The Experimental Forest provides food and cover for about 150 species of birds, other wild animals, and domestic livestock. Interest in animals by visitors ranges from that of birders expanding their life lists to the desire of children from urban areas to see a "real cow." Wood produced during treatment of the forested areas for various management objectives helps support a small wood products industry.

Four terms are used in the following sections to distinguish timbered areas of various sizes. They are defined as follows:

Treatment Area—A large area of up to several hundred acres that is treated during a single period of cutting. Equivalent to a small "sale area" in timber sales contracts.

Stand—A subdivision of a treatment area that is several acres in size. Minimum area of a stand will vary with such factors as class of ownership and the objectives of management. In the Montane Zone, stands will probably be 5 acres or larger. The term is used as in management texts and is applicable to an area of even-aged or many-aged trees that can be regenerated by a single reproduction method. In addition, a stand is large enough to be mapped and to serve as a practical unit for growth estimation.

Patch—An area of trees of relatively uniform density, tree quality, and age structure that is too small to be treated as a stand. It cannot receive individual consideration in mapping, inventory, and growth prediction. Small patches occur so frequently, they merit separate consideration, as in the next definition.

Group—A small, even-aged patch of trees such as results from a single application of group selection. Groups will usually range in area from ½ to 1 acre.

Although mentioned only briefly, vegetative types other than ponderosa pine are important resources of the Zone. They create a desirable diversity in scenery and in uses made of the land. Other vegetative types include grasslands, Douglas-fir groups and stands, aspen groves, streamside willow thickets, and blue spruce. Douglas-firs occur as scattered trees in pine stands as well as in pure patches and stands on north-facing slopes and along streams. Retaining young, vigorous Douglas-firs in pine stands will usually be beneficial.

Stand Characteristics

Biological characteristics of ponderosa pine stands that influence selection of silvicultural practices are highly variable in the Montane Zone (fig. 1). Most obvious are variations in stand density, age class distribution, tree vigor, presence of diseases and insects, and size of the patches of uniform density and age structure that make up the forest mosaic. Present conditions are the result of past logging, insect and disease attacks, fires, and irregularity in the coincidence of weather and other factors favorable to regeneration. Although the stands are far removed from virgin condition, they bear little resemblance to a fully managed, regulated forest. A practical attempt to select treatments requires that the multitude of minor variations be logically collected in a few broad classes of characteristics.

Figure 1.—Ponderosa pines of the Montane Zone form a complex mosaic of variations in tree size and stand density.

Frequently, events of the past have created patches and stands that, by accident, appear to have resulted from application of standard reproduction methods. It is convenient to regard these resemblances as intentional, and to plan and carry out treatments in terms of these methods. By ignoring structural variations that involve only scattered small patches, three general situations can be recognized. These situations, to be considered when selecting treatments, are:

Situation 1.—Many areas large enough to be managed as uneven-aged stands have an irregular mosaic of small, even-aged patches of trees. Such stands resemble the results attainable from group selection cuttings at irregular time intervals. Each even-aged group covers an area equal to what could be fully occupied by a few mature trees, prehaps ½ to 1 acre.

Situation 2.—Other stands are made up of patches that are individually smaller than the 5 or more acres of a manageable stand but larger than ½ to 1 acre. Such a patch is, therefore, too large to resemble a group resulting from usual applications of group selection.

Situation 3.—Some stand-size areas appear to be even-aged or two-storied, as though regenerated by uniform shelterwood, seed tree, or clearcutting methods. Many stands properly classed as being in this situation appear highly irregular before treatment. Cuttings necessary to improve the health, vigor, and appearance of such stands, however, will produce greater uniformity in density and age structure.

Recognition of any of the three situations listed here must be based on the real management problem and not on correctable accidents of past stand history.

Factors in addition to stand condition call for flexibility in the silvicultural prescriptions for ponderosa pine. Some factors are of major importance for most classes of ownership and most management objectives applicable to the Zone. The principal forest values derived from the Zone relate to beauty of the landscape and to various forms of outdoor recreation. Silviculture, in most areas, is not a tool to obtain maximum production of wood products. Instead, it is a means of improving the quality and diversity of the landscape and of providing as high a potential for a variety of uses as is compatible with carrying capacity of the land. Silviculture thus

becomes a landscaping tool and a means of reducing the damage from mountain pine beetles, dwarf mistletoe, and other agents that can lower the attractiveness and usefulness of the Zone. Wood products produced while these improvements are being made help keep alive an industry that is important to Colorado.

Since the values received from the Zone relate largely to scenery and recreation, the question may be raised: "Why do any cutting at all?" Nontreatment is not a suitable alternative for interior ponderosa pine for several reasons. These include:

1. Patches and stands that are old and diseased must be replaced to create the scenic and recreation areas of the future. Untouched, they can only become more unattractive with the passage of time (fig. 2). It is possible to grow ponderosa pines to advanced ages, although they do not reach the ages in the central and southern Rocky Mountains that they do to the north and west (Sudworth 1917). The difficulty is that too many of our larger trees have already reached a diseased and lightning-scarred old age. Regenerating patches or stands while they can still produce seeds avoids the high costs and risks of planting. Reproduction from seed can accumulate over several years so there is no dependence on planting during what may be a year of adverse weather conditions.

2. Dense patches and stands of young ponderosa pines on areas of low site quality will stagnate. Tree diameters stay small for many years and the problem is not relieved by natural thinning (Myers and Van Deusen 1960). Evidence of slow growth in unthinned stands includes such examples as trees more than 60 years old with average diameters of 2.5 inches. Dense patches and stands are unattractive; impede use by people, deer, and cattle; block the view of more scenic areas; and create a biological desert on the forest floor (fig. 3). Ponderosa pines in the Montane Zone of central Colorado grow on areas of low site quality and are, thereby, subject to stagnation. They must be thinned, if of high density, to avoid the disadvantages of stagnation.

3. Any patch or stand that is not already stagnated will become more dense with the passage of time. Crowding reduces tree growth and vigor and increases susceptibility to damage. For example, high stand density can lead to devastating losses from mountain pine beetles.[3] A survey of past outbreaks in the Montane Zone indicated that epidemic losses can occur even in

[3] *Sartwell, Charles, and Robert E. Stevens. Mountain pine beetle in ponderosa pine: Prospects for silvicultural control in second-growth stands. (Manuscript submitted for publication.)*

Figure 2.—Heavy infestations of dwarf mistletoe greatly reduce scenic beauty and timber yields.

Figure 3.—Dense patches of ponderosa pine contribute little to the appearance and productivity of the Montane Zone.

years of ample rainfall (Beal 1943). Also, increased density will interfere with or prevent the development of a community of understory shrubs and herbaceous plants. This reduces the scenic value of the area and the food supply of wild and domestic animals.

Types of Treatments

Variability of the ponderosa pine type and of its uses usually requires application of several cutting methods to a single treatment area.The alternative is to use drastic methods to move the stands toward some predetermined structure. The Manitou Experimental Forest treatments are examples of how variable a single marking job can be. The cutting methods used at Manitou, described in standard nomenclature, were:

1. Thinning—Reduction of the density of even-aged groups and stands. Thinnings were applied where densities before treatment were high enough to greatly reduce the growth of the trees and the herbaceous ground cover. Young trees left after final removal of a shelterwood were also thinned, if necessary. Trees varying more than 20 years in actual age sometimes appeared to have the diameter distributions of even-aged stands because of unequal diameter growth caused by past irregularity in density. Such patches and stands were treated as though they were truly even-aged.

Nature of the thinnings varied with size of the trees and stand conditions created by past damage or cutting. Most precommercial thinnings and commercial cuts in trees of small average diameter were heavy low thinnings (thinnings from below). Emphasis was on removal of the lowest crown classes and enough dominants and codominants to stimulate growth of the residuals. Some dense groups and stands were overtopped by isolated larger trees, poor quality residuals of the previous generation that remained alive after logging or fires. These stands and most of those composed of large trees only were cut by free thinning procedures, as defined by Smith (1962). In free thinning situations, low thinning was accompanied by (a) removal of scattered overstory trees, (b) felling of undesirable dominants, and (c) any necessary release among the dominant and codominant trees of the main stand.

2. Improvement—Removal of badly diseased and dying trees that interfered with or overtopped those selected for future growth. Improvement cutting was done where (a) patches or stands not dense enough to require complete thinning had occasional trees that should be removed, or (b) single poor trees remained over even-aged patches. Past fires and logging in the Montane Zone have left most present stands badly in need of improvement cutting. Application of all needed improvement at once could materially degrade scenic and other values. It may be desirable to make two or more improvement cuts in stands where many trees should be removed, and where the effects of further delay can be tolerated.

3. Clearcutting with or without planting—Removal of patches or stands of trees so badly infested with dwarf mistletoe that they could not produce seed and were dying rapidly.

4. Seed cut of uniform shelterwood—Reduction of the density of mature trees to encourage the establishment of natural regeneration over an area large enough to be treated as a stand.

5. Final cut of uniform shelterwood—Removal of overstory trees to release an adequately stocked understory. Prior cutting and natural disturbances affecting entire stands occurred so long ago that cuttings resembling removals prior to final cuts were not needed.

6. Group selection—Removal of a group of mature trees with intent to obtain natural regeneration from seeds produced adjacent to the area occupied by the group. When following specifications for group selection, it is imperative that markers do not create some of the poor stand conditions they are trying to prevent. Old and declining trees must not be retained just because they are relatively small and thus appear younger than they are. Chances for this error are especially great with ponderosa pine, where a tendency to stagnate often results in poor correlation between tree age and diameter. If the marker is to leave the younger, more vigorous trees, he must be sure he is doing so. If all the trees in a stand are old and declining, regeneration under a shelterwood may be appropriate.

Selecting Treatments

Prescriptions for treatment areas at Manitou (200 to 600 acres each) called for concurrent application of all six methods. Improvement cutting and thinning were accomplished in even-aged groups and stands, where necessary. Each stand to be regenerated in whole or part was cut according to a single reproduction method, selected to meet the needs of the stand and the management objectives for the forest.

Occasional interior patches of quite dissimilar conditions, however, were treated on the basis of their status and not on that of the stand as a whole. Otherwise, good trees would have been sacrificed for the sake of uniformity. For example, patches of young, vigorous trees in stands marked for shelterwood seed cuts were thinned, if necessary. Additional considerations in applying the cutting methods are described in the section "**Applying Treatments.**"

When evaluating stand density as an indicator of the need for thinning or of space requirements for regeneration, the real indicator of competition is not visible. Degree of crown closure is not a useful guide under the dry conditions of the Montane Zone. Instead, the extent of site occupancy by tree roots determines tree vigor and ease of regeneration. Ponderosa pine stands are adequately stocked when the crowns are still well separated. This is why some managers define proper stocking as 50 to 60 percent of the "room to grow and none to waste" values of normal yield tables. With the principal factors determining degree of site occupancy underground, the system of designating stocking goals described in the next section, **Reserve Stands**, provides a useful guide for marking crews. Root competition appears to be a less serious factor in Colorado than in Arizona, and more important than in the Black Hills.

Most areas to be regenerated were cut according to prescriptions for group selection or uniform shelterwood. In applying shelterwood cuts to even-aged and two-storied stands (**situation 3** of the section titled **Stand Characteristics**), the regeneration period of each stand was begun or terminated by the cutting. Selection of a seed or final cut depended on the presence or absence of younger trees. A pine understory, if adequate in amount and quality, was regarded as the logical consequence of prior shelterwood cuts. Appropriate parts of uneven-aged stands were regenerated by group selection. Where the even-aged units were about ½ to 1 acre in area, the cut covered the entire area of each selected group (**situation 1**). With patches larger than ½ to 1 acre, the poorest parts of scattered patches of old trees were cut as single groups (**situation 2**). These parts were selected on the basis of advanced age, low tree vigor, high incidence of disease, and a very low density. Occasionally, however, large patches of rapidly declining trees were marked for a shelterwood seed cut, to avoid the undesirable effects of delayed treatment. Groups (**situation 1**) or parts of patches (**situation 2**) not cut for regeneration received an improvement cut, a thinning, or were left alone. Clearcutting was classed as a drastic treatment to be avoided except where there was no alternative for solving severe disease problems.

Reproduction appeared to be adequate in amount by the third year after each cutting and, after 6 years, remains abundant on regeneration areas of the first treatment (fig. 4). Length of the period of germination and establishment can vary at Manitou and elsewhere with weather conditions and with position of the treatment year in a seed production cycle. Areas under a shelterwood, in cleared groups of ½ to 1 acre, and in the narrower parts of clearcut areas all regenerated satisfactorily. Good range management practices and moderate grazing use are expected to prevent significant future losses of pine seedlings to livestock (Heerwagen 1954).

Figure 4.—Group selection and shelterwood provide the openings needed for ponderosa pine seedlings to become established.

Presence of a suitable seed source is essential to natural regeneration. For best results, trees depended upon for seed should be 60 to 160 years old. Older and younger trees, however, do produce viable seeds. Seed trees must not have a dwarf mistletoe rating (fig. 5) greater than 3.0.[4] With group selection and clearcutting with natural regeneration, none of the cleared area should be more than about 150 ft from an acceptable seed tree.

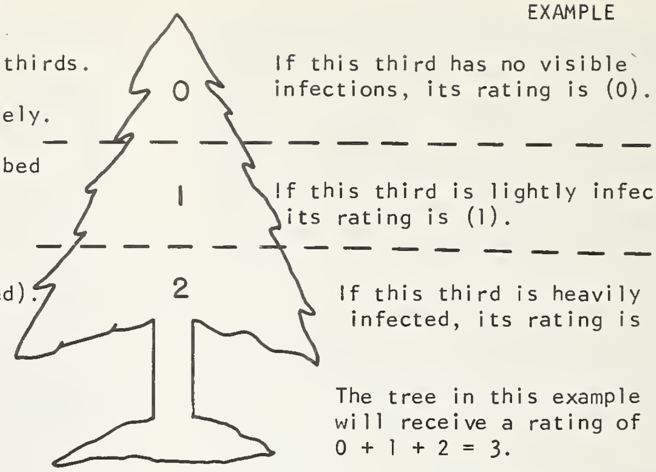
[4]Personal communication with Frank G. Hawksworth, Chief Plant Pathologist, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

INSTRUCTIONS

STEP 1. Divide live crown into thirds.

STEP 2. Rate each third separately. Each third should be given a rating of 0, 1 or 2 as described below.
(0) No visible infections.
(1) Light infection (1/2 or less of total number of branches in the third infected).
(2) Heavy infection (more than 1/2 of total number of branches in the third infected).

STEP 3. Finally, add ratings of thirds to obtain rating for total tree.



EXAMPLE

If this third has no visible infections, its rating is (0).

If this third is lightly infected, its rating is (1).

If this third is heavily infected, its rating is (2).

The tree in this example will receive a rating of 0 + 1 + 2 = 3.

Figure 5.—Instructions for and example of the use of the 6-class mistletoe rating system (Hawksworth 1961).

Regeneration problems of the Montane Zone can be described further by explaining why certain standard reproduction methods were not used at Manitou. Single-tree selection was not used because: (1) no areas would be freed of root competition to provide space for reproduction, (2) nothing could be done to reduce dwarf mistletoe infestations, and (3) the method was rarely in accord with the age or size structure of any stand. Shelterwood was chosen over the seed-tree method to increase the chances of getting adequate natural regeneration within a few years of cutting. Regeneration can be successful when a good seed supply coincides with weather conditions favorable for germination and seedling establishment. By leaving more seed-producing trees, there will be more years when the seed supply per acre is adequate and, thus, more opportunities for coincidence with favorable weather conditions. Also, the volume left in a shelterwood is enough to justify its eventual removal to favor the new stand.

An appropriate cutting method for each stand condition on a treatment area should be selected during marking. As the marker moves from one condition to another, he should ask himself a series of questions, such as:

—Does this unit cover a large enough area to be treated as a single stand?
—If so, which of the three general types of structure does it most resemble?
—If it is not a stand, should I treat the unit separately from the rest of the stand?
—Can I leave the unit alone until the next entry into the entire treatment area?
—If it should be treated, are the trees old enough and of such condition that I should consider a regeneration cut?
—If so, is there any advance reproduction?
—If a regeneration cut is in order, what do I want this unit to look like in the future and what regeneration method will produce what I want?
—If regeneration is not appropriate now, do I want to thin or is an improvement cut to remove a few undesirable trees called for?
—Now that I have tentatively selected a type of marking for this unit, must I modify it because of effects on the scenery, on wildlife habitat and food supply, or on the soil?

A marker need not concern himself with the effect of his choice of method on logging costs. Under Montane Zone conditions, logging costs are not expected to depend to any important degree on the type of regeneration method selected. This assumption has been tested in detail and accepted as correct elsewhere in the ponderosa pine type (McDonald et al. 1969).

In summary, each patch or stand of a treatment area should receive the treatment most appropriate to its condition, usually without regard to the cutting method used on adjacent patches or stands. Posttreatment status of adjacent areas must be considered if they are to serve as seed sources. It is unnecessary to attempt creation of larger, more uniform stands, although this will often happen because existing stand conditions do not permit many alternatives. Maintenance of irregularity is acceptable, even desirable, so long as it will not perpetuate intolerable conditions of disease or high stand density.

One restriction may limit freedom in use of the six cutting methods listed above: Individual clearcuts for disease control along regularly traveled forest roads should be no larger than the ½- to 1-acre units of group selection. Other than that, roadside strips need no special treatment. Cuttings continue to the roads without change in density of the reserve stand or other specifications.

Once a cutting method is selected for a patch or stand, it is marked to accomplish management objectives and to leave the best trees at the desired density. With one exception, basal area reserves for intermediate cuts at Manitou equaled growing stock level 80, as defined in the next section, **Reserve Stands**. Level 80 was selected as the best compromise to achieve all objectives of the treatments. Growing stock level 100 would have been chosen if major emphasis had been placed on timber production.

Posttreatment observations and data support selection of level 80, as follows:

1. Treated stands are open enough to provide pleasing views into the stands and to allow the growth of wildflowers, yet are not so open as to lessen the scenic impact of the forest or to lose the forest environment.
2. Total wood production in ft^3 of stands repeatedly thinned to level 80 was estimated to be about 85 percent of the maximum possible for average site quality of the treated areas.
3. With any reasonable cutting cycle, basal areas of trees large enough to support brood populations of mountain pine beetles will not again reach the potential danger level of 150 ft^2 per acre.[5]
4. When basal area of large trees is 80 ft^2 per acre, production of forbs and grasses at Manitou is 15 percent of that from areas without a tree cover. Herbaceous production is not materially different from that of open areas, however, after small-diameter trees have been thinned to lower basal areas appropriate to their size. These relationships, with the great reduction in density that usually results from application of the prescriptions described here, indicate suitable conditions for profitable livestock operations.[6]
5. Allowable stocking of livestock on the treatment areas at Manitou increased an average of 10 percent annually in the first 6 years after the beginning of cutting.[6]
6. Forage available for wildlife has not been measured, but appears to have increased at a rate similar to that of forage used by livestock.

The one exception to level 80 as a stocking standard was the thinning of dense patches of small-diameter trees to level 160, or twice usual basal areas. Trees in dense groups or stands are tall in relation to their diameters because of the unequal effects of density on height and diameter growth. Slender trees are very subject to snow bend and snow break for about 6 years after thinning, a period of adjustment of bole form in response to increased exposure (Myers 1963). Probability of a wet spring snow before form adjustment is completed is high in the Montane Zone. Higher posttreatment density was expected to provide enough well-formed trees to permit leaving a group of adequate density after a second thinning in about 10 years.

Potential problem areas for snow damage may be identified in two ways. Patches or stands with a pretreatment density of four or more times the basal area of level 80 (table 1) are subject to heavy snow damage after thinning. Likewise, trees may bend or break after thinning if their height-diameter ratios equal or exceed 90. This ratio is obtained by dividing total height by d.b.h. outside bark, both in the same units of measure.

Reserve Stands

Numbers of trees standing after partial cutting is a major factor in attaining the objectives of intermediate and regeneration cuts. A numerical system for designating stocking goals is desirable so both the manager and the field crews have a common understanding of what is needed. The system must be flexible because management objectives and relative emphasis on forest values can vary from area to area. The system described below has been used with success in the Montane Zone, both in planning and in actual marking for cutting. It applies to even-aged stands and to the even-aged groups created by group selection.

Stand density after treatment is expressed as a relationship between basal area and average stand diameter after cutting (fig. 6). Results of thinning studies and data from temporary plots in even-aged stands were used to obtain regression equations of desired basal area on average stand diameter for stands of average site quality. "Best" stand density for each average diameter sampled was based on a forecast of production in ft^3 and probable length of saw-log rotations. Solution of the regression equations produced the line labeled 80 in figure 6 and the basal areas of table 1. A level is named by the basal area desired when average diameter is 10.0 inches (fig. 6). Basal areas increase with diameter until 10.0 inches diameter is reached,

[5]*See footnote 3.*

[6]*Personal communication with P.O. Currie, Principal Range Scientist, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.*

Table 1.--Basal areas after partial cutting in relation to average stand diameter, growing stock level 80

Average stand d.b.h. after cutting (Inches)	Basal area per acre	Average stand d.b.h. after cutting (Inches)	Basal area per acre	Average stand d.b.h. after cutting (Inches)	Basal area per acre	Average stand d.b.h. after cutting (Inches)	Basal area per acre
	ft^2		ft^2		ft^2		ft^2
2.0	12.1	4.0	35.2	6.0	56.6	8.0	72.5
2.1	13.2	4.1	36.4	6.1	57.6	8.1	73.1
2.2	14.4	4.2	37.6	6.2	58.5	8.2	73.7
2.3	15.5	4.3	38.7	6.3	59.4	8.3	74.3
2.4	16.7	4.4	39.9	6.4	60.3	8.4	74.8
2.5	17.9	4.5	41.0	6.5	61.2	8.5	75.3
2.6	19.0	4.6	42.2	6.6	62.1	8.6	75.8
2.7	20.2	4.7	43.4	6.7	62.9	8.7	76.3
2.8	21.3	4.8	44.5	6.8	63.8	8.8	76.7
2.9	22.5	4.9	45.7	6.9	64.6	8.9	77.1
3.0	23.7	5.0	46.8	7.0	65.4	9.0	77.5
3.1	24.8	5.1	47.8	7.1	66.2	9.1	77.9
3.2	26.0	5.2	48.8	7.2	67.0	9.2	78.2
3.3	27.1	5.3	49.8	7.3	67.7	9.3	78.5
3.4	28.3	5.4	50.8	7.4	68.5	9.4	78.8
3.5	29.5	5.5	51.8	7.5	69.2	9.5	79.1
3.6	30.6	5.6	52.8	7.6	69.9	9.6	79.3
3.7	31.8	5.7	53.8	7.7	70.6	9.7	79.5
3.8	32.9	5.8	54.7	7.8	71.2	9.8	79.7
3.9	34.1	5.9	55.7	7.9	71.9	9.9	79.8
						10.0+	80.0

Derived from: $B = 11.58495\ D - 11.09724$ $\quad 2.0 \leq D \leq 5.0$

$B = 7.76226\ D + 0.85289\ D^2 - 0.07952\ D^3 - 3.45624$ $\quad 5.0 < D < 10.0$

- - - - - - - - - - - - - - - - - - - METRIC EQUIVALENT - - - - - - - - - - - - - - - - - - -

Average stand d.b.h. after cutting (cm)	Basal area per ha	Average stand d.b.h. after cutting (cm)	Basal area per ha	Average stand d.b.h. after cutting (cm)	Basal area area ha	Average stand d.b.h. after cutting (cm)	Basal area per ha
	m^2		m^2		m^2		m^2
5.0	2.7	10.0	7.9	15.0	12.8	20.0	16.5
5.5	3.2	10.5	8.4	15.5	13.2	20.5	16.8
6.0	3.7	11.0	9.0	16.0	13.7	21.0	17.0
6.5	4.3	11.5	9.5	16.5	14.1	21.5	17.3
7.0	4.8	12.0	10.0	17.0	14.5	22.0	17.5
7.5	5.3	12.5	10.5	17.5	14.8	22.5	17.7
8.0	5.8	13.0	11.0	18.0	15.2	23.0	17.9
8.5	6.4	13.5	11.5	18.5	15.5	23.5	18.0
9.0	6.9	14.0	11.9	19.0	15.9	24.0	18.2
9.5	7.4	14.5	12.4	19.5	16.2	24.5	18.3
						25.0	18.4
						25.4	18.4

Derived from: $B = 1.04706\ D - 2.54758$ $\quad 5.0 \leq D \leq 12.7$

$B = 0.70156\ D + 0.03035\ D^2 - 0.00111\ D^3 - 0.79344$ $\quad 12.8 \leq D \leq 25.4$

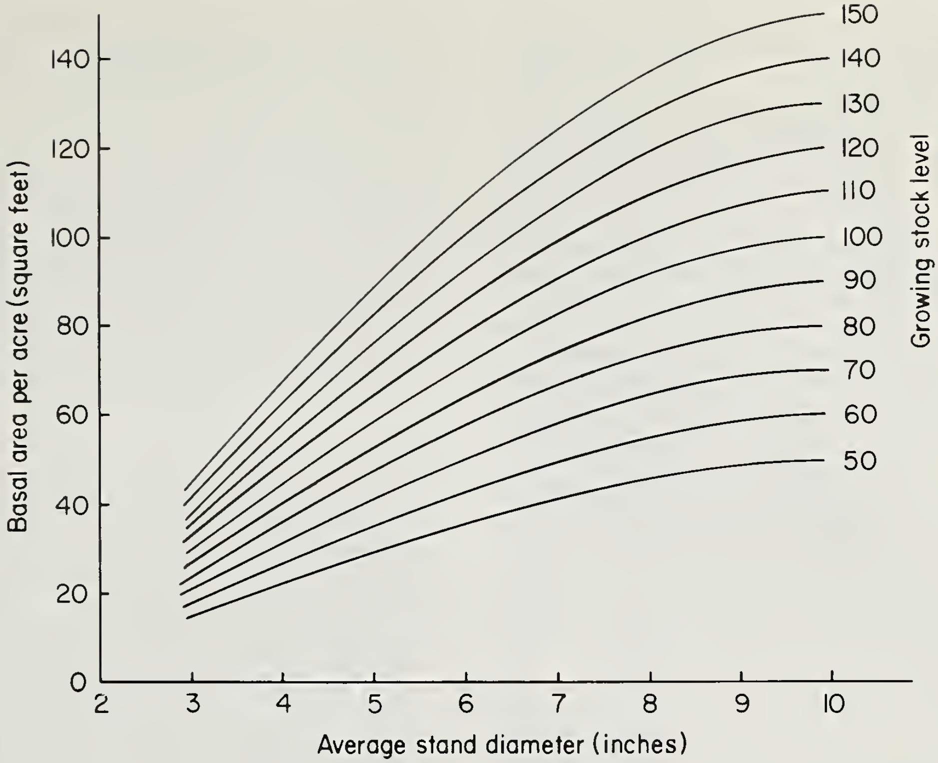


Figure 6.—Basal area after thinning in relation to average stand diameter for standard levels of growing stock.

and remain constant thereafter. The designation "growing stock level 80" indicates that basal area is to be 80.0 ft^2 when average stand diameter after cutting is 10.0 inches or larger.

Desired stand density will vary with the objectives of management; therefore, more than one growing stock level must be defined (fig. 6). The original relationship (level 80) serves as a base from which the basal areas of other levels can be determined. To obtain basal areas for any growing stock level, multiply each value for level 80 in table 1 by the ratio: level/80. Level is the constant basal area desired when average diameter is 10.0 inches or larger. For example, to obtain basal areas for level 100, multiply each value for level 80 in table 1 by 100/80 or 1.25. How basal areas vary with growing stock level in stands of equal average diameter is shown in table 2.

Marking crews may prefer to use average distance between trees rather than basal area as a guide to reserve stocking. In such cases, table 1 or the equivalent for another stocking level is converted to a table of distances. The steps are:

1. Divide basal area per acre by the basal area of a tree of average diameter to obtain the reserve number of trees per acre.

Table 2.--Basal areas after partial cutting in relation to average stand diameter, growing stock levels 40 to 120

Average d.b.h. after cutting (Inches)	Basal area in ft^2 when growing stock level is--				
	40	60	80	100	120
1.0	1.8	2.8	3.7	4.6	5.6
2.0	6.0	9.1	12.1	15.1	18.1
3.0	11.8	17.7	23.7	29.6	35.5
4.0	17.6	26.4	35.2	44.1	52.9
5.0	23.4	35.1	46.8	58.5	70.2
6.0	28.3	42.5	56.6	70.8	85.0
7.0	32.7	49.0	65.4	81.7	98.1
8.0	36.3	54.4	72.5	90.6	108.8
9.0	38.8	58.1	77.5	96.9	116.3
10.0+	40.0	60.0	80.0	100.0	120.0

2. Divide 43,560 by the reserve number of trees per acre to obtain the area in ft² available to each tree.

3. Obtain the square root of the area available per tree. This is the average distance between trees, assuming a uniform spacing on a grid of squares.

Equivalent distances for the level and diameter combinations of table 2 and for larger diameters are given in table 3.

Table 3.--Growing stock levels for ponderosa pine, expressed as average distance between residual trees

Average d.b.h. after cutting (Inches)	Average distance between residual trees, in ft, when growing stock level is--				
	40	60	80	100	120
1.0	11.4	9.3	8.0	7.2	6.6
2.0	12.5	10.2	8.9	7.9	7.2
3.0	13.4	11.0	9.5	8.5	7.8
4.0	14.7	12.0	10.4	9.3	8.5
5.0	15.9	13.0	11.3	10.1	9.2
6.0	17.4	14.2	12.3	11.0	10.0
7.0	18.9	15.4	13.3	11.9	10.9
8.0	20.5	16.7	14.5	13.0	11.8
9.0	22.3	18.2	15.8	14.1	12.9
10.0	24.4	19.9	17.2	15.4	14.1
11.0	26.8	21.9	19.0	17.0	15.5
12.0	29.2	23.9	20.7	18.5	16.9
13.0	31.7	25.9	22.4	20.0	18.3
14.0	34.1	27.9	24.1	21.6	19.7
15.0	36.6	29.8	25.8	23.1	21.1
16.0	39.0	31.8	27.6	24.7	22.5
17.0	41.4	33.8	29.3	26.2	23.9
18.0	43.9	35.8	31.0	27.7	25.3
19.0	46.3	37.8	32.7	29.3	26.7
20.0	48.7	39.8	34.5	30.8	28.1

- - - - METRIC EQUIVALENT - - - -

Average d.b.h. after cutting (cm)	Average distance between residual trees, in m, when growing stock level is--				
	9.2	13.8	18.4	23.0	27.5
5.0	3.8	3.1	2.7	2.4	2.2
10.0	4.5	3.6	3.1	2.8	2.6
15.0	5.3	4.3	3.7	3.3	3.0
20.0	6.2	5.0	4.4	3.9	3.6
25.0	7.3	6.0	5.2	4.6	4.3
30.0	8.8	7.2	6.2	5.5	5.1
35.0	10.2	8.4	7.2	6.5	5.9
40.0	11.7	9.6	8.3	7.4	6.8
45.0	13.2	10.7	9.3	8.3	7.6
50.0	14.6	11.9	10.3	9.2	8.4

Stand density specifications described above create an estimation problem when average diameter after cutting will be less than 10.0 inches. The basal area to be left is based on the as yet unknown posttreatment average diameter. It is therefore necessary to estimate diameter after cutting and to determine the basal area goal from table 1 or equivalent. Experience on a number of treatment areas has shown that crews adapt readily to this procedure. Estimates of the effects of cutting on average diameter, such as in table 4, can be helpful in training but do not replace actual changes observed during marking.

Table 4.--Average stand diameters before thinning and after thinning to various levels

Average d.b.h. before thinning (Inches)	Average d.b.h. in inches when percent of trees remaining after thinning is--				
	10	30	50	70	90
3.0	4.7	4.0	3.8	3.5	3.1
4.0	6.0	5.1	4.8	4.5	4.2
5.0	7.2	6.2	5.8	5.5	5.2
6.0	8.4	7.3	6.9	6.6	6.2
7.0	9.6	8.4	7.9	7.6	7.2
8.0	10.8	9.5	9.0	8.6	8.2
9.0	11.9	10.6	10.0	9.6	9.2
10.0	13.0	11.7	11.1	10.7	10.3

Markers must remember that level 80 does not mean a reserve basal area of 80 ft² per acre unless average d.b.h. after cutting is 10.0 inches or larger. For smaller average diameters, level 80 means that less, sometimes much less, than 80 ft² be left (see table 1). Also, reserve basal area is determined for each individual group or stand treated, not as an average for widely dissimilar conditions.

Marking crews should first walk through each part of the treatment area to determine the type of cutting required and to obtain a mental picture of the group or stand that should be left. Many patches are so small that a marker in the middle of the area can see the patch boundaries. Minor adjustments in the estimate of average diameter after cutting can be made, if necessary, as marking continues. Basal areas of leave trees should be checked periodically with a prism or other angle gage. Inspection of table 1 and of variable-density yield tables (Myers 1971) shows that a high degree of precision is not necessary. Specifications for precommercial thinnings can be presented to the cutters in

the form of previously marked demonstration plots, as described in the next section.

Applying Treatments

Selecting a cutting method for each group or stand, and marking to leave the basal area of the growing stock level chosen are major activities. There are, however, additional tasks to be completed and decisions to be made before the areas are ready for treatment. Some of the more important ones are described below.

Marking for Thinning

Most thinnings can be controlled by marking either the trees to be taken or those to be left. If cutting removes only trees too small for posts or small poles, it may be more efficient to exercise control through demonstration marking. In the latter case, several patches of trees, each of different average tree diameter, should be marked to the residual basal areas desired. This can be done by flagging the reserve trees. Members of the thinning crews visit these sample areas as often as necessary for them to become familiar with the spacings and densities desired for various average diameters. Flagged patches remain unthinned until they are no longer needed as demonstrations.

Slash Disposal

Several methods of slash disposal were tried at Manitou, with varying degrees of success. Piling and burning proved to be so expensive and time consuming that it was soon abandoned. Spot burning was much better if the residual stands were sufficiently open and if the loggers made an effort to keep slash accumulations away from reserved trees. Lopping and scattering required no burning but did require extra effort along roads to get the slash close to the ground and less conspicuous.

Current slash disposal practices involve removing as much slash as possible in the form of small posts and firewood. Commercial cutters remove usable material 2 inches in diameter and larger, and lop and scatter the remaining tops. Areas are also provided for individuals who want only small amounts of firewood for personal use. Removal of posts and fuelwood leaves only small material that does not adversely affect appearance or use of the area (fig. 7).

Wildlife Trees

Before marking trees for removal, those in use as nests or dens by birds and other animals can be tagged with metal signs (4×6 inches at Manitou), reading "Do not cut this tree" (fig. 8).

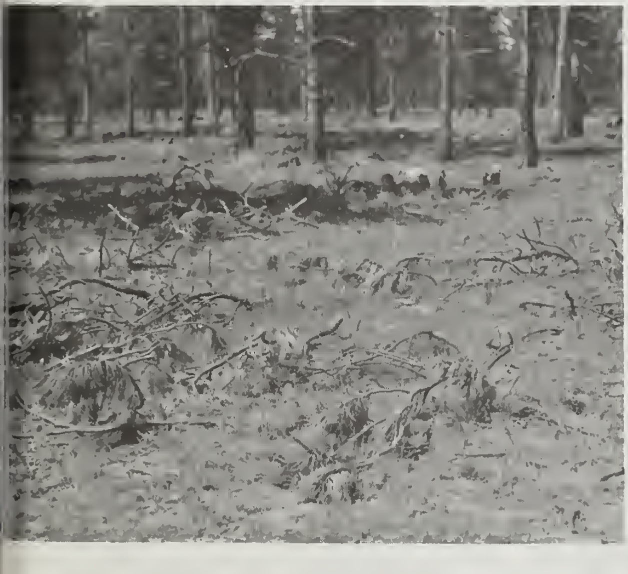


Figure 7.—Removal of all useful material, including fireplace wood, will usually solve slash disposal problems.

Figure 8.—Trees beneficial to wildlife are valuable elements of Montane Zone stands.

Markers do not paint-spot tagged trees for cutting, and sales contracts warn purchasers that tagged trees are not to be cut during felling of dead and cull trees. Most reserved wildlife trees at Manitou were ponderosa pines used by violet-green swallows, mountain chickadees, Williamson's sapsuckers, and yellow-bellied sapsuckers. Elsewhere in the Montane Zone, the reservation of aspens will also be important, especially for flammulated owls and tree swallows. Ponderosa pines 11 to 30 inches d.b.h. are preferred for food and cover by Abert's squirrels (Patton and Green 1970). Conditions are improved when the rather uniform spacings that usually result from partial cuttings are interrupted by occasional clumps of three or four closely spaced large trees.[7] Maintenance of squirrel populations, therefore, requires that conversion of large areas to seedling and sapling stands be avoided. Development of scattered, young stands of reasonable area creates no special problems. Abert's squirrels in central Arizona were observed to occupy home ranges averaging about 18 acres in summer and fall and 5 acres in winter (Keith 1965).

The low-vigor, large-limbed, or dead trees used by wildlife would be prime choices for removal if special effort were not made to save them. So few trees per acre are involved in this type of habitat maintenance that their preservation will have negligible adverse effect on the appearance of the forest and other values. Regardless of the silvicultural methods applied, tagged trees should remain untouched so long as they are useful to wildlife.

Dwarf Mistletoes

Dwarf mistletoes create a major disease problem in ponderosa pine stands of the Montane Zone that must be considered in planning timber treatments. In general, partial cutting cannot improve the growth and quality of an infested stand if the average DMR (dwarf mistletoe rating) (see fig. 5), is greater than 3.0 (Myers et al. 1972). If the average DMR of an infested stand is less than 3.0, cutting methods are applied as usual except that the cutting of infected trees and pruning of diseased lower branches are emphasized (Lightle and Hawksworth 1973). Pruning that removes more than half the live crown or leaves less than one-third the total tree height in live crown can result in decreased growth or death (Dahms 1954, Gordon 1959). Also, pruning is expensive. If dwarf mistletoe control requires severe pruning of a tree, there should be a good reason for not removing it.

If the DMR of a stand is greater than 3.0, dwarf mistletoe becomes a major factor affecting treatment decisions. The objective should be to use methods that minimize abrupt impacts on scenic and other values. Five possible solutions to problems created by heavy infestations are available:

1. **Leave immature patches and stands alone** if (a) the mortality rate is not extreme, (b) partial cutting is not justified for reasons other than stand improvement, and (c) adjacent stands have no special values that require immediate protection. At Manitou, several small, severely infected patches surrounded by large treated areas of lower density were left undisturbed to serve as wildlife cover. They were isolated from adjacent healthy trees by cutting enough diseased trees to leave strips 50 ft wide. The infected patches will be treated after nearby areas have become dense enough to be attractive to wildlife.
2. **Thin immature patches and stands** if reduced density is needed to improve scenic or other values. No direct benefits to timber production or improvement in stand quality can be expected.
3. **Apply a shelterwood seed cut** to infected mature trees still capable of producing seed, but without a pine understory. Since each potential seed producer must have a DMR of 3.0 or less, seed trees may be hard to find in heavily infested stands. Schedule shelterwood removal before the new stand is more than 3 ft tall or 10 years old.
4. **Apply a shelterwood final cut** where mature trees occur over an acceptable understory of younger pines. Thin and prune the young stand, with emphasis on reducing the dwarf mistletoe infestation in the former understory.
5. **Clearcut small areas** if the stand is breaking up and other solutions are not applicable. Make the boundaries of the cleared areas irregular to minimize impact on the landscape. Regeneration is obtained from natural seeding or planting, depending on width of the cleared area and condition of adjacent stands. None of the cleared area should be more than about 150 ft from an acceptable seed tree if natural regeneration is desired. Heavy infestations of dwarf mistletoe are confined to ridges on the Manitou Experimental Forest. In similar situations, it may be appropriate to manage part of the area of cleared upper south slopes for browse production.

[7]Personal communication with David R. Patton, Principal Wildlife Biologist, Rocky Mountain Forest and Range Experiment Station, Forest Hydrology Laboratory, Tempe, Arizona.

It is sometimes possible to reduce the number of trees cut for dwarf mistletoe control without increasing the danger of infecting adjacent trees and stands. Bole infections where the stem is larger than 5 inches in diameter are of low vigor and produce few dwarf mistletoe seeds (Mark and Hawksworth 1974). Such infections therefore are unlikely sources of additional infection and the tree may be left, if needed, to meet scenic or other objectives.

Other Damaging Agencies

In addition to dwarf mistletoe, ponderosa pine is subject to other damaging agencies of varying importance in the Montane Zone. Some of these are:

1. Mountain pine beetle—A major pest that lowers scenic values, kills landscape trees on homesites, and reduces the yield of wood products. The possibility of reducing the area of new infestation through control of stand density was mentioned in a previous section. Post-treatment stand densities should be sufficiently low that basal areas will not increase enough to exceed 150 ft^2 before the time of the next planned cut. The possibility of exceeding this level can be checked by producing a yield table for the stand in question, using actual initial stand values (Myers 1971, Myers et al. 1972). Cutting to control existing beetle infestations must be done outside the period of emergence, about July 15 to September 10 in the Montane Zone (McCambridge 1964). A forest pest control specialist should be consulted before control is undertaken.

2. Heart rots—For safety reasons, the presence and degree of infection by heart rots must be considered when selecting reserved trees along roads, in campgrounds, and other places where use by forest visitors is concentrated. Red rot, fortunately, is unimportant in the Montane Zone as compared to the Black Hills and the Southwest (Andrews 1971).

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Scientific Names of Species Mentioned

Abert's squirrel	*Sciurus aberti ferreus* True
Aspen	*Populus tremuloides* Michx.
Blue spruce	*Picea pungens* Engelm.
Douglas-fir	*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco
Dwarf mistletoe	*Arceuthobium vaginatum* subsp. *cryptopodum* (Engelm.) Hawksworth and Wiens
Flammulated owl	*Otus flammeolus* Kaup
Mountain chickadee	*Parus gambeli* Ridgway
Mountain pine beetle	*Dendroctonus ponderosae* Hopkins
Ponderosa pine	*Pinus ponderosa* Laws.
Red rot	*Polyporus anceps* Peck
Tree swallow	*Iridoprocne bicolor* Vieillot
Violet-green swallow	*Tachycineta thalassina* Swainson
Williamson's sapsucker	*Sphyrapicus thyroideus* Cassin
Willow	*Salix* spp.
Yellow-bellied sapsucker	*Sphyrapicus varius* L.

Myers, Clifford A.
1974. Multipurpose silviculture in ponderosa pine stands of the Montane Zone of central Colorado. USDA For. Serv. Res. Pap. RM-132, 15 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

Presents silvicultural prescriptions for ponderosa pine in an area where several uses and products of the forest are important but scenic and recreation values predominate. Although far from virgin condition, the pine stands now bear little resemblance to a managed, regulated forest. Present diversity within and between vegetative types can and should be maintained.

Keywords: Forest cutting systems, *Pinus ponderosa*, silviculture, stand condition, thinning (trees), timber management.

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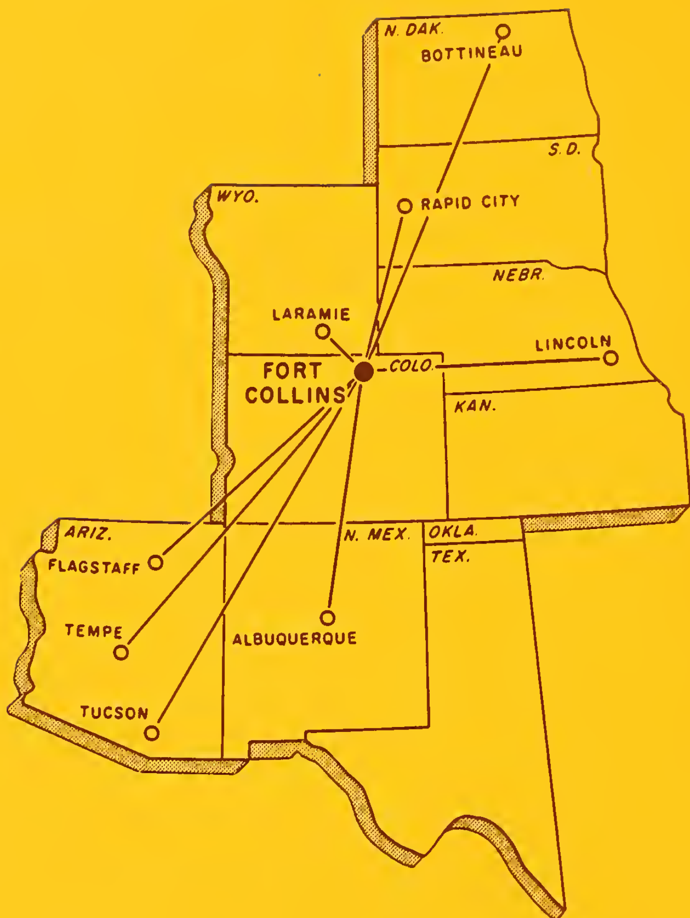
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